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Piston compressor for compressing gaseous media in at least two working chambers

The invention relates to a piston compressor for compression of gaseous media in at least two working chambers, having the features of the independent claim.

Numerous piston compressors with a plurality of working chambers are already known and in use. For example, US 4 889 039 describes a piston compressor in which the valves are each arranged in the cylinder casing. Compressors such as these are relatively costly to produce, and are correspondingly expensive. One major disadvantage of a valve arrangement in the cylinder casing is the relatively large dead-space volumes, which result in poor compression efficiency particularly in the case of relatively small compressors with small swept volumes.

One object of the present invention is therefore to avoid the disadvantages of the known compressor, in particular to create a compressor of the type mentioned initially which is distinguished by the capability to produce it easily and at low cost, while at the same time having good performance data. One particular aim is to allow easy assembly based on a modular design. The compressor should also have a long life.

According to the invention, this object is achieved by a piston compressor having the features of the independent claim.

A piston compressor for compression of gaseous media has a stepped piston with a first piston part and at least one second coaxially arranged piston part. The piston compressor has a first cylinder with an internal bore for holding the first piston part in order to form a first working chamber. The second

cylinder likewise has an internal bore for holding the second piston part, in order to form a second working chamber. In this case, the second piston part has a smaller diameter than the first piston part. Each of the at least two cylinders is closed by a plate with valve arrangements, with the second piston part, which has a smaller diameter, being passed through an opening in one of the plates with valve arrangements. The stepped piston can move in a reciprocating manner in the compressor, with induction of the gaseous medium, which is then compressed. The stepped piston allows compression in at least two separate working chambers. One working chamber is in this case in the form of an annulus (annular gap) while the other working chamber is cylindrical. The reciprocating movements of the stepped piston may, for example, be provided via a connecting-rod system, which is driven via a crank drive. For this purpose, the stepped piston is connected to the drive via a piston rod or a guide piston. Thus, in particular, the stepped piston could be formed on a crosshead of a compressor motor.

The plates with valve arrangements close the cylinders and are used to control the inlet and outlet of the gaseous medium to be compressed. A valve arrangement such as this has various advantages. For example, the plates with the valve arrangements can be installed and removed easily. This likewise allows a modular design, since the necessary valves can be fitted to the plates easily. The advantages of this design are good utilization of the cylinder cross section and that the valve plates move freely without friction. The dead space, the wear and the flow losses are thus low with this valve arrangement, and it is therefore particularly suitable for relatively small and high-speed compressors.

In a first embodiment, the first piston part is arranged at one end of the second piston part. The piston part with the large diameter thus forms the front end of the stepped piston. The first piston part forms a cylindrical working chamber, and the second, smaller piston part forms an annular working chamber. The piston parts of the two cylinders are thus arranged in such a manner that compression takes place alternately. The gaseous medium is in each case compressed in one working chamber, and is sucked in in the other working chamber in one movement direction (and vice versa).

Since the gas forces which act on one hand on the entire piston surface and on the other hand only on the annular gap are partially cancelled out in the working chambers, this reduces the load produced by the forces on the drive. A further effect of this arrangement is a balanced torque profile and thus quieter running.

In one alternative embodiment, the second piston part is arranged at the end of the first piston part. In consequence, the second piston part, whose diameter is smaller than the diameter of the first piston part, forms the front end of the stepped piston. The second, smaller piston part forms a cylindrical working chamber, and the first, larger piston part forms an annular working chamber. The piston parts and the two cylinders are arranged in such a manner that compression takes place "on the same stroke". In this arrangement, one movement direction has the same effect on each of the two working chambers. Compression thus takes place at the same time in the two working chambers. However, compression takes place in two stages. In a first stage, compression takes place via the annular gap (which is formed by the second working chamber). The second stage of

the compression takes place via the piston surface of the second piston part, which forms the front end of the stepped piston.

Each of the piston parts is preferably sealed by means of piston rings from the internal bore in the cylinder parts. The advantage of this embodiment is that the losses take place via the piston rings from the second stage into the first stage, and not into free space. This makes it possible to considerably reduce gas losses. Furthermore, the loads on the piston rings are reduced.

By way of example, the diameter of the second, smaller piston part in comparison to the diameter of the first, larger piston part is preferably chosen such that the annular gap volume of the first stage has a volume which is three to four times as large as the working chamber at the front end of the stepped piston.

It is advantageous for the plates to be in the form of disks and to bound the working chambers at the end, thus closing the working chambers in a simple manner. This allows the compressors to be designed to be simple and compact.

It is advantageous for plates with valve arrangements to have at least one inlet valve and at least one outlet valve. This ensures that air or other gaseous media are in each case sucked in via one inlet valve in one movement direction, with the compressed air being ejected via the outlet valves during the opposite movement. For this purpose, the plates advantageously have bores for the valve arrangements. The appropriate valves can be arranged on these bores. Such bores can be incorporated with little effort on the plates, which are preferably composed of metal such as steel or aluminum.

It is particularly advantageous for the inlet valves and outlet valves to be in the form of lamellar valves, tongue valves or individual valves with spring resetting. A lamellar closes (or opens) the passage through in each case one bore for the media to pass through. A tongue closes (or opens) the passage through a plurality of bores in each case, for the media to pass through at the same time. An individual valve closes (or opens) the passage through one bore or a plurality of bores in each case, for the media to pass through. Valves such as these are particularly suitable for use in a compression unit with small swept volumes. These valve types are distinguished in that they can be produced or obtained very easily. They can also be arranged in the plate in a simple manner and at low cost.

The plates are sealed from the cylinder parts by means of seals, for example flat seals, an O-ring seal or, possibly, metallic seals.

Further individual features and advantages of the invention will become evident from the following description of the exemplary embodiments, and from the drawings, in which:

Figure 1 shows a cross section through a first exemplary embodiment of a piston compressor according to the invention,

Figure 2 shows a cross section through an alternative exemplary embodiment of a piston compressor according to the invention,

Figure 3 shows an enlarged illustration of a section through the upper part of a piston compressor with lamellar valves, and

Figure 4 shows an enlarged illustration of a partial cross section through a further piston compressor with valves which have spring resetting.

Figure 1 illustrates a piston compressor, which is annotated 15, with a stepped piston 1. The stepped piston 1 comprises two piston parts: a first piston part 16 and a second piston part 17. The pistons are, of course, arranged to be fundamentally symmetrical and coaxial on an axis A. The stepped piston 1 can move in a reciprocating manner in the x direction along the axis A. The first piston part 16, which defines the front end of the stepped piston, is arranged in a first cylinder 7. The diameter of the first piston part 16 is larger than the diameter of the second piston part 17. A working chamber 21, which is formed by the first cylinder 7, is located above a piston surface 30 of the first cylinder 7, closed by the valve plate 9. A further working chamber 22 is arranged in the area of the second cylinder 8 and of the second piston part 17. As can be seen, this working chamber 22 is annular.

In Figure 1, the compressor 15 also has a cylinder head 29. In this case, the plate 9 is located between the cylinder head 29 and the first cylinder 7. It is also possible to dispense with the illustrated cylinder head 29 and to use only one plate 2 with a valve arrangement as a closure for the cylinder 7.

The other plate 9 with the valve arrangements, which closes the annular gap or working chamber 22, is arranged between the first cylinder 7 and the second cylinder 8. In the middle, the plate 2

has a circular opening 20, whose diameter preferably corresponds to the diameter of the internal bore 19 of the second cylinder 8. However, the opening 20 may also be designed in such a way as to provide a seal with the piston part 17. At least one inlet valve 3 or 13 and one outlet valve 4 or 14, respectively, are arranged on the plates 2 and 9. For example, in Figure 1, the inlet valves 3 and 13 and the outlet valves 4 and 14 are in the form of lamellar valves 31. Other valve types may, of course, also be used. The piston parts 16 and 17 have piston rings 5 on their outer surfaces, in order to seal the respective working chambers 21 and 22. Other seals such as labyrinth seals or rod packing are likewise feasible. The front piston part 16 furthermore has guide elements 6 in order on the one hand to improve the robustness of the stepped piston 1 and on the other hand in order to minimize the distance between the stepped piston 1 and the cylinder (in this case only the cylinder part 7). This makes it possible to improve the efficiency of the piston compressor 15.

By way of example during the downward movement in the x direction, the stepped piston 1 compresses a gaseous medium in particular air, in which case the compressed medium can be injected via the outlet valve 14. The gaseous medium is sucked into the first working chamber 21 by the same downward movement. When the stepped piston 1 moves in the opposite direction, the process is reversed. The arrows shown in Figure 1 illustrate the air flowing in and flowing out.

Figure 2 shows one alternative embodiment of a piston compressor 15. This piston compressor 15 compresses air or other gaseous media on the same stroke. Thus, for example, when a stepped piston 1 is arranged at the front, that is to say by way of example moving in the direction of the cylinder head 29, then the air in

the working chambers 21 and 22 is compressed. When the pressure in the working chambers exceeds a specific level, then the compressed air escapes via the respective outlet valves 4 or 14.

The compression process takes place in two stages. In a first stage, the medium is compressed via the annular gap 28 in the lower working chamber 21. In the second stage, the medium is compressed in the front working chamber 22 via the piston surface 30 of the front piston 17. In this case, higher final pressures can be achieved because of the relatively small piston area 30. The arrangement is distinguished inter alia in that the losses take place via the piston rings 5 from the second stage into the first stage, and thus not in the free space. Gas losses can thus be considerably minimized. Furthermore, the loads on the piston rings 5 are minimized since the assisting high pressure in the lower working chamber 21 means that the differential pressure acting on the piston rings 5 with respect to the front working chamber 22 is reduced. In addition to piston rings 5, the second piston part 16 has additional guide elements 6. A plurality of such sealing elements and/or guide elements may be arranged, depending on the design and purpose.

Figures 1 and 2 do not show the actual drive for the stepped piston 1. A stepped piston 1 is moved by an oscillating drive, for example via a crank drive. The stepped piston 1 is in this case preferably connected to the drive via a piston rod. The stepped piston 1 may, in particular, be guided by a crosshead (likewise not illustrated).

Figure 3 shows a section through an upper plate 9, illustrating an inlet valve 3 in the form of a lamellar valve 31. A bore 23 in the form of an aperture hole can be provided in the plate 9 for in each case one inlet valve 3, and is covered by a respec-

tive lamellar. The lamellar valves 31 are in this case fitted off-center. At least one lamellar in each case can be provided overall as an inlet and outlet valve. The number of lamellars depends essentially on the physical size and on the intended performance data. The piston parts 16 and 17 must, of course, have cutouts at points when components of the valves 3 and 4 project into the swept volume. The position of the stepped piston 1 around the longitudinal axis A must be fixed.

The inlet valves 3 and outlet valves 4 may in each case also be in the form of tongue valves, corresponding to the embodiment with lamellar valves 31, in which case one tongue would then at the same time cover a plurality of bores 23 (not illustrated).

By way of example, Figure 4 shows a valve arrangement on a plate 9, which also corresponds analogously to the valve arrangement of the plate 2 of the annular gap 28. The valves 3 and 4 are in the form of individual valves with spring resetting 33, and are arranged centrally over the bores 23.

The other plates (which are each not illustrated in Figure 3 or 4) may, of course, be plates with similar valve arrangements.

The individual valve designs of lamellar, tongue or individual valves are not the subject matter of the invention. These have been described in detail in many specialist publications and are assumed to be already known.